



MIOCENE MOLLUSKS FROM THE LOWER PART OF THE BEAR LAKE FORMATION ON UKOLNOI ISLAND, ALASKA PENINSULA, ALASKA

Louie Marincovich, Jr.¹

ABSTRACT. Fossiliferous strata of the Bear Lake Formation crop out on Ukolnoi Island, Alaska Peninsula, southwestern Alaska. The molluscan fauna has an age of 15–16 Ma, or earliest middle Miocene, which is the greatest known age for any Bear Lake outcrop. A similar age is suggested by mollusks for an additional outcrop on an unnamed peninsula to the northeast of Cape Aliaksin on the adjacent Alaska Peninsula mainland. The latter outcrop is the only one known where mollusk-bearing Bear Lake strata are inferred to be in contact with mollusk-bearing strata of the Paleogene Stepovak Formation. The co-occurrence of some molluscan species on Ukolnoi Island and at Cape Aliaksin, plus a radiometric age of 10.4 ± 0.49 Ma for an andesite flow overlying marine strata at the latter site, indicate a middle Miocene age for the Unga Conglomerate Member of the Bear Lake Formation at Cape Aliaksin. The age inferred from the mollusks at these three localities suggests assignment of these strata to the lower part of the Bear Lake Formation.

The Ukolnoi Island molluscan faunule of 18 species lived at depths of about 25 to 35 m in a cool-temperate habitat. The presence of some warm-temperate to subtropical Asian taxa suggests that this faunule lived during the peak of the middle Miocene warm interval known throughout the North Pacific region.

INTRODUCTION

The Bear Lake Formation is the thickest and most extensively distributed Miocene marine unit on the Alaska Peninsula of southwestern Alaska (Figs. 1, 2), where it crops out discontinuously in a structurally complex area adjacent to potentially oil-producing offshore basins in Bristol Bay. The age range of this unit has not been well documented, owing to the scarcity of well-preserved megafossils at many outcrops and the virtual absence of age-diagnostic microfossils in the generally coarse, near-shore Bear Lake sediments. The most abundant megafossils in the Bear Lake Formation, and the principal means of dating the formation, are bivalve and gastropod mollusks that commonly have uncertain age limits. Many Bear Lake outcrops have been well dated with mollusks, although these data are largely unpublished, but ages of the top and base of the formation have been difficult to ascertain. The presumed uppermost beds of the formation

contain poorly preserved mollusks, and the stratigraphically lowest beds, on Ukolnoi Island, were recognized only very recently (Marincovich and Kase, 1986). The Ukolnoi Island strata were questionably assigned to the Unga Conglomerate Member of the Bear Lake Formation by Burk (1965) and to the unrestricted Bear Lake Formation by Marincovich and Kase (1986). The base of the Bear Lake section on Ukolnoi Island is not exposed, but presumably lies upon Paleogene rocks of the Stepovak Formation (Burk, 1965). As noted below, a fossiliferous Bear Lake outcrop containing reworked Stepovak mollusks recently has been found on the Alaska Peninsula mainland.

The present report is the first comprehensive description and illustration of a fossil faunule from the Bear Lake Formation. As such, it is a beginning effort in the task of describing and understanding the entire sequence of Bear Lake molluscan faunas and placing them in the broader context of worldwide geologic and paleontologic events of the Cenozoic.

Grewingk (1850) probably was the first to examine Bear Lake mollusks, because he reported two species from Tertiary rocks at "Bai Moller" (Port Moller; Fig. 2), where the only Tertiary marine rocks that crop out are now assigned to the Bear Lake Formation (Burk, 1965). The first scientist to personally collect Bear Lake mollusks was W.H. Dall, who discovered many outcrops bearing Tertiary megafossils during expeditions from 1865 to 1899. Strata with Miocene mollusks and plants collected on the Alaska Peninsula mainland or in the adjacent Shumagin Islands (Fig. 2), and much later assigned to the Bear Lake Formation (Burk, 1965), were referred to by Dall (1892, 1896, 1904) as the "Kenai Group" or the "Astoria Group," based upon inferred similarities with floras of Cook Inlet, Alaska, or with faunas of Oregon and

1. U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, and Research Associate, Invertebrate Paleontology Section, Natural History Museum of Los Angeles County.

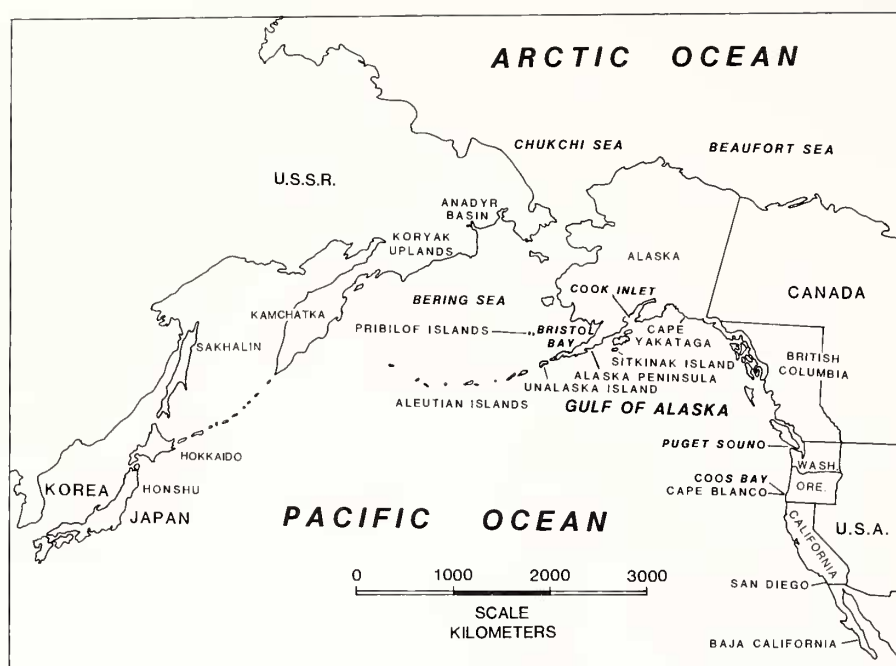


Figure 1. Index map of the North Pacific region, showing localities mentioned in text.

Washington, respectively. Some molluscan faunas thought to be of Miocene age by Dall, particularly those on Unga and Popof islands, in the Shumagin Islands (Fig. 2), were later assigned to the Stepovak Formation of Eocene and Oligocene age (Atwood, 1911; Burk, 1965). Bear Lake mollusks were examined next by MacNeil (*in* Burk, 1965), who referred specimens from around the margins of Port Moller and from the nearby formational type section at Bear Lake (Fig. 2) to the late Miocene. A small collection of mollusks from strata assigned to the Unga Conglomerate Member of the Bear Lake Formation at Cape Aliaksin (Fig. 2) was thought to be of early middle Miocene age by MacNeil (1973). This age was inferred by MacNeil (1973) from the presence at Cape Aliaksin of mollusks supposedly similar to early Miocene California species and late Oligocene or early Miocene Japanese species, as well as from the presence at one of several unspecified "nearby sites" of the presumed middle Miocene bivalve *Mytilus middendorffi* Grewingk, 1850. No mollusk with a well-documented time-stratigraphic range was reported from Cape Aliaksin itself by MacNeil (1973). The Unga Conglomerate Member, thought to be the basal member of the Bear Lake Formation (Burk, 1965), later was tentatively assigned to the upper Newportian or lower Wishkahan molluscan Stage by Allison (1978), based on tenuous species-level ties to other North Pacific faunas, whereas beds he referred to as the "unnamed upper member" of the Bear Lake Formation were assigned to the Wishkahan Stage. Allison's (1978) age estimates were based on the presence of species known in molluscan faunas assigned to stages in Oregon and Washington (Addicott, 1976), and his inferred Bear Lake faunal age range corresponded to the ages of the stage

boundaries in the Pacific Northwest. At the time he wrote, Allison's (1978) inferences indicated an age range of latest early Miocene to middle Miocene for the Unga Conglomerate Member and late middle Miocene to late Miocene for his "unnamed upper member." Subsequently refined age inferences for these Pacific Northwest molluscan stages (Addicott, 1981) suggested an age range of late middle Miocene to early late Miocene for the Bear Lake faunas considered by Allison (1978). Mollusks from several outcrops between Port Heiden and Bear Lake (Fig. 2), including the more northerly and possibly the younger Bear Lake exposures, were considered to be of middle(?) and late Miocene age by Marincovich (*in* Dettnerman and others, 1981). The oldest confidently dated Bear Lake outcrop is the present one on Ukolnoi Island, which is among the most southerly Bear Lake exposures. This Ukolnoi Island faunule was assigned an earliest middle Miocene age by Marincovich and Kase (1986), based on the presence of *Turritella (Hataiella) sagai* Kotaka, 1951. This gastropod was previously known only in Japanese strata, some of which have been dated using planktonic microfossils and radiometric techniques and assigned an age range of about 15–16 Ma (Marincovich and Kase, 1986).

The present study relates the importance of two Bear Lake molluscan faunules, a relatively large one on Ukolnoi Island and a smaller and approximately coeval one on the Alaska Peninsula mainland (Table 1). The most confidently identified species are useful for supporting the earliest middle Miocene age inferred for the Ukolnoi Island faunule by Marincovich and Kase (1986). These two faunules allow, for the first time, insights into the nature of the marine environment during deposition of the earliest known Bear Lake sediments,

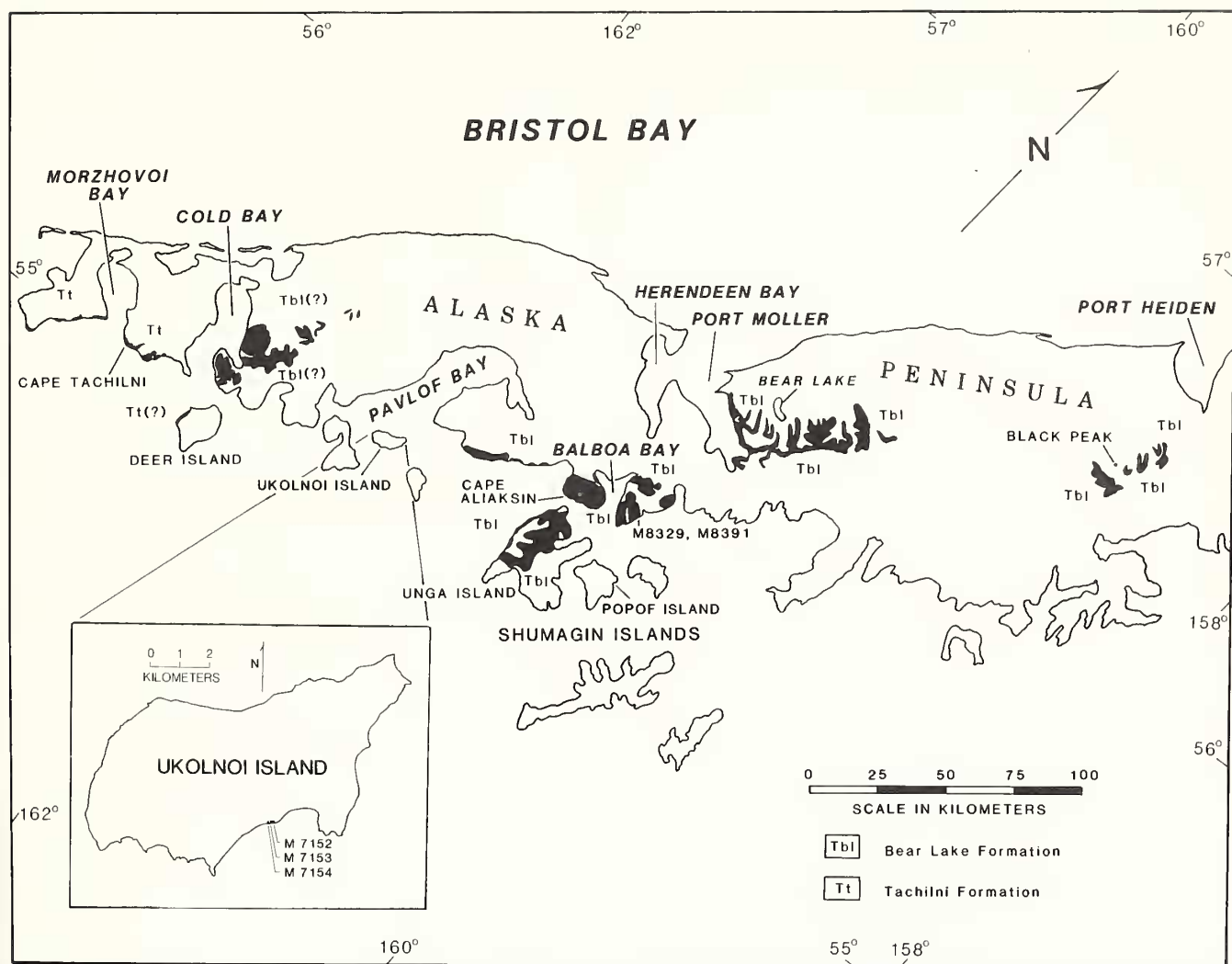


Figure 2. Index map of the Alaska Peninsula, showing localities mentioned in text and the outcrop extent of the Tertiary Bear Lake and Tachilni formations. Numbers preceded by M are USGS fossil localities.

as well as inferences about the ages of adjacent Bear Lake outcrops.

Most of the mollusk specimens used in this study were collected on July 4, 1977, when the helicopter in which I was a passenger made an unplanned landing on the southern coast of Ukolnoi Island due to the abrupt onset of high winds, rain, and fog. Marine sediments were not then thought to be present on the island. Discovery of the Ukolnoi Island marine faunule in coastal bluffs was made while escaping the confines of the helicopter and waiting for the weather to clear. Because of the need to fly elsewhere as soon as the weather abated, I was able to spend only about one hour collecting mollusks. There was insufficient time to make detailed observations on, for example, taphonomy, community structure, or precise stratigraphic occurrences of fossils. No attempt was made to measure the stratigraphic section. Planned visits to this stratigraphic section in 1982, 1983, and 1985 by other U.S. Geological Survey personnel, who were not primarily inter-

ested in paleontologic studies, resulted in some additional fossil specimens, but no stratigraphic or sedimentologic data.

THE AGE OF THE BASE OF THE BEAR LAKE FORMATION

Since the report of *Turritella (Hataiella) sagai* on Ukolnoi Island by Marincovich and Kase (1986), this species has been recognized in one of two faunules of the Bear Lake Formation (USGS localities M8329 and M8391) on the Alaska Peninsula mainland that also contain reworked Paleogene mollusks of the Stepovak Formation. The presence of this turritellid at M8329 provides a correlation with Ukolnoi Island strata and indicates that this mainland outcrop (Fig. 2) is also of earliest middle Miocene age. The fact that these two faunules contain mixed Bear Lake and Stepovak mollusks (as detailed below), and are inferred herein to immediately overlie an erosional unconformity, reinforces the interpretation that T.

Table 1. Mollusks from the Bear Lake Formation on Ukolnoi Island (M7152–M7154) and at one Alaska Peninsula mainland site (M8329). Numbers indicate specimens found at each locality.

	M7152	M7153	M7154	M8329
BIVALVES				
<i>Acila</i> sp. indet.	1			1
<i>Yoldia</i> sp. indet.	1			
<i>Mytilus</i> (<i>Plicatonytilus</i>) <i>gratacapii</i> Allison and Addicott, 1976		1		
<i>Lucinoma acutilineata</i> (Conrad, 1849)	9	10	11	
<i>Macoma</i> sp. indet.	8	9	6	
<i>Clinocardium</i> sp.	2			
<i>Pitar?</i> sp.	2		1	
<i>Mya</i> (<i>Mya</i>) <i>truncata</i> Linnaeus, 1758	4			2
<i>Mya</i> sp. indet.	2			
<i>Penitella</i> sp. indet.		3		
<i>Thracia</i> sp. indet.		3	2	
GASTROPODS				
<i>Turritella</i> (<i>Hataiella</i>) <i>sagai</i> Kotaka, 1951	12	9	11	1
<i>Natica</i> (<i>Cryptonatica</i>) <i>clausa</i> Broderip and Sowerby, 1829			3	
<i>Fusitriton oregonensis</i> (Redfield, 1846)			1	
<i>Colus?</i> sp.	1			
<i>Neptunea</i> (<i>Neptunea</i>) aff. <i>N. (N.) lyrata altispira</i> Gabb, 1869		2		
<i>Beringius crebricostatus</i> (Dall, 1902)	1	1		
<i>Tyrannoberingius rex</i> Marincovich, 1981		1		
SCAPHOPOD				
<i>Dentalium</i> (<i>Rhabdus</i>) cf. <i>D. (R.) schencki</i> Moore, 1964	14	10		

(*H.*) *sagai* is a marker for the stratigraphically lowest Bear Lake beds. This interpretation implies that the Ukolnoi Island faunule also lies close to the base of the Bear Lake Formation. Although the base of the Bear Lake Formation on Ukolnoi Island is not exposed (R. Detterman, oral communication, 1986), the molluscan faunule there is considered herein to be stratigraphically near to the presumably underlying Stepovak Formation.

One specimen of *T. (H.) sagai* was found at M8329, along the eastern coast of an unnamed peninsula to the northeast of Cape Aliaksin and about 80 km to the northeast of Ukolnoi Island (Fig. 2). A contact between the Bear Lake Formation and underlying Paleogene Stepovak Formation was mapped there by Burk (1965), and is herein inferred to be an erosional unconformity, based on interpretation of the mollusks there. The faunule at M8329 contains intermixed Bear Lake and Stepovak mollusks, and it is considered herein to be stratigraphically low within the Bear Lake Formation. Along with *T. (H.) sagai*, the Bear Lake faunule at locality M8329 contains *Mya* (*Mya*) *truncata* Linnaeus, 1758, a well-known bivalve of middle Miocene to Holocene age. Also present at M8329 is an *Acila* that occurs in other Bear Lake Formation faunules but is as yet unidentified (Marincovich, unpublished data, 1987). Overlying and stratigraphically close to M8329 is another Bear Lake faunule (locality M8391; Fig. 2) that contains Stepovak mollusks such as *Mya* (*Arenomya*) *kusi-*

roensis Nagao and Inoue, 1941, which is reported in late Eocene or early Oligocene faunas of Hokkaido and Alaska. The Japanese record of *M. (A.) kusiroensis* from the Shitakara Formation of the Urahoro Group was thought to be of late middle Oligocene age by MacNeil (1965), but is now considered to be either of early Oligocene age, based on mollusks (Honda, 1986), or of late Eocene age based on planktonic foraminifers (Kaiho, 1983). The most significant Alaskan occurrence of this species is in the Stepovak Formation on the northwest shore of Popof Island (Fig. 2), about 20 km south of M8329, where MacNeil (1965) cited *M. (A.) kusiroensis* in the upper part of the *Acila shumardi* Zone. This molluscan zone was defined in the Pittsburg Bluff Formation of Oregon that is thought to be of late Eocene and early Oligocene(?) age by Armentrout and others (1983). Other Alaska occurrences of *M. (A.) kusiroensis* are in middle(?) Oligocene strata of the Poul Creek Formation and possibly the lower Eocene to lower Oligocene Kulthieth Formation near Cape Yakataga (Fig. 1) in the eastern Gulf of Alaska (MacNeil, 1965; Plafker, 1987). The mixture of inferred earliest middle Miocene plus late Eocene and early Oligocene(?) mollusks on the Alaska Peninsula at M8329 and M8391 suggests a significant hiatus between the Bear Lake Formation and the Stepovak Formation, namely the absence of middle and upper Oligocene and lower Miocene strata. The probability of this hiatus was inferred by Burk (1965, p. 91)

without citing evidence from a specific locality. The mixed Bear Lake and Stepovak faunules at M8329 and M8391 substantiate Burk's (1965) general observation. To my knowledge there are no other outcrops where mollusks from these two formations occur together.

One of the Ukolnoi Island gastropods, *Tyrannoberingius rex* Marincovich, 1981, has been reported previously only from its type locality at Cape Aliaksin (Fig. 2) (Marincovich, 1981), in strata assigned to the Unga Conglomerate Member (Burk, 1965). As noted below in the discussion of *T. rex*, an andesite flow overlying the marine Tertiary strata at Cape Aliaksin has a potassium-argon age of 10.4 ± 0.49 Ma (Frederic Wilson, written communication, 1986) and places this minimum-age constraint on the underlying molluscan fauna. If *T. rex* is restricted in age to middle Miocene faunas, which is an interpretation allowed by its Cape Aliaksin occurrence, then its presence in the Ukolnoi faunule is further general confirmation for the age of the latter fauna.

PALEOECOLOGY OF THE UKOLNOI ISLAND FAUNULE

The paleobathymetry inferred for the Ukolnoi Island molluscan faunule is within the inner part of the inner shelf zone, at approximately 25 to 35 m. Living equivalents of about half of these genera or species range into the intertidal zone, but several taxa do not. Among the latter (with their minimum depths in the modern northeastern Pacific noted here and in the taxonomic section that follows) are: *Acila* (*Truncacila*) (5 m), *Lucinoma annulata* (Reeve, 1850) [living homologue of the extinct *L. acutilineata* (Conrad, 1849)] (20 m), *Pitar* (25 m), *Beringius* (35 m), *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby, 1829 (9 m), *Turritella* (20 m), and *Dentalium* (5 m). The relative scarcity and abraded and broken condition of Ukolnoi Island *Mytilus* (*Plicatomytilus*) *gratacapii* Allison and Addicott, 1976, which is well preserved in great abundance at several other Bear Lake outcrops and which is inferred to be a shoreline indicator, also supports an inferred habitat somewhat deeper than the very shallow subtidal zone. In addition, *Mytilus s.l.* is reported in this region in depths no greater than 40 m, and *Mya* (*Mya*) *truncata* Linnaeus, 1758, in depths not over 50 m.

The habitats of living individuals or homologues of several Ukolnoi Island mollusks indicate a cool-temperate marine climate for this faunule. *Mya* (*Mya*) *truncata* has a modern circumboreal range, but ranges southward in the eastern Pacific to at least Puget Sound, Washington (the southern limit of the cool-temperate realm), and possibly to northern California, and its range extends to northeastern Honshu in the western Pacific (Bernard, 1979). *Natica* (*Cryptonatica*) *clausa* is another species that has a modern circumboreal distribution but also ranges far to the south: to San Diego, southern California, in the eastern Pacific and to Japan and Korea in the western Pacific. It lives in depths from 9 to 970 m, in progressively deeper water from north to south. It is present in numerous North Pacific fossil faunas that range in inferred paleotemperature from mild temperate to cold (Marincovich, 1977). *Fusitriton oregonensis* (Redfield, 1846) does not occur

in the modern Arctic Ocean, but still has a broad latitudinal distribution, from the Pribilof Islands, Bering Sea (south of the line of floating winter ice), to southern California in the eastern Pacific, and to the east and west coasts of central Honshu in the western Pacific. The species is reported in depths from the intertidal zone to 2,370 m, in generally greater depths from north to south (Smith, 1970). It occurs in depths of 10–420 m in the Gulf of Alaska (Smith, 1970), and in depths from the subtidal zone to 100 m in British Columbia (Bernard, 1970). Similarly to *N. (C.) clausa*, this species occurs in a large number of fossil faunas that range in inferred paleotemperature from temperate to cold (Smith, 1970). *Lucinoma annulata* ranges from southern Alaska to Mexico in depths from 20 to 800 m, and occurs abundantly (as in the Ukolnoi Island faunule) within the inner shelf zone (0–100 m) (Burch, 1944).

The living mollusks noted above indicate that the marine climate when the Ukolnoi faunule lived was cool-temperate, in the sense of Hall (1964), who stated that there are fewer than four months per year when shallow-water temperatures are warmer than 10°C (50°F) at the northern limit of this marine climatic zone. The modern cool-temperate zone ranges from 48°N to 56°N (Puget Sound to the Gulf of Alaska) in the northeastern Pacific, and from 41°N to 43°N (northernmost Honshu to eastern Hokkaido) in the northwestern Pacific (Hall, 1964).

The abundance of the warm-temperate to subtropical turritellid, *T. (H.) sagai*, in the cool-temperate Bear Lake fauna is anomalous. The limited presence of this turritellid in Alaska, on Ukolnoi Island and at M8329 on the mainland, suggests that the incursion of *T. (H.) sagai* northeastward from Honshu to Alaska was brief. Based upon the established chronostratigraphic range of *T. (H.) sagai* in Japan, such an incursion coincided with the height of the earliest middle Miocene warming trend recognized in the North Pacific region (Savin and others, 1981). The presence of the warm-water bivalve *Pitar*, questionably identified from Ukolnoi Island herein, also suggests an eastward migration from the western Pacific. The movement of molluscan veligers from Honshu to southwestern Alaska may have been aided by a brief northward incursion of warm water into the North Pacific that is associated in modern times with El Niño conditions. Sporadic occurrences of warm-water mollusks in otherwise cool- or cold-water faunas, due to periodic northward incursions of warm water, have been well documented in modern faunas of southern California and inferred for Pleistocene faunas there (Zinsmeister, 1974), and may also account for the similar extralimital occurrence of *T. (H.) sagai* in Alaska. However, anomalous warm-water species in southern Californian Pleistocene faunas usually occur as single individuals or as very small populations (Zinsmeister, 1974), whereas *T. (H.) sagai* is prolifically abundant on Ukolnoi Island. Based on the well-documented ecology and paleoecology of cool-water taxa such as *Beringius*, *Fusitriton*, and *Neptunea*, these taxa would certainly have been excluded from the Ukolnoi Island faunule had the water temperature been as warm as it was for Japanese occurrences of *T. (H.) sagai*. It is possible that the Ukolnoi Island population of *T.*

(*H.*) *sagai* was able to exist in cool-temperate conditions, even though the previously reported occurrences of this species are in Japanese warm-temperate to subtropical faunas (Kotaka, 1959). One probable explanation for this apparent paleoecologic anomaly is that collections from Ukolnoi Island do not have extremely precise locality data. Based on my observations on Ukolnoi Island, *T. (H.) sagai* and *Dentalium* cf. *D. schencki* Moore, 1964, occur together, each prolifically, in a single stratigraphic interval, to the exclusion of most other taxa. However, the poor weather conditions that forced our helicopter to land on Ukolnoi Island in 1977, and which led to the accidental discovery of this faunule, also precluded making stratigraphically well controlled collections. As noted above, subsequent collections by other geologists also were not precisely located. This leaves the possibility, noted above, that *T. (H.) sagai* did occur in southwestern Alaska only during a brief warm climatic interval.

FAUNAL COMPARISON WITH THE TACHILNI FORMATION

The Tachilni Formation of early late Miocene age crops out on the distal part of the Alaska Peninsula and contains a cool-temperate, inner-shelf molluscan fauna (Marincovich, 1983). Its type section at Cape Tachilni (Fig. 2) and its limited outcrop area are about 80 km southwest of the nearest Bear Lake formation outcrop, on Ukolnoi Island, and the two formations have many molluscan genera in common. However, despite their geographic proximity and similarity in inferred habitat, a comparison of the Tachilni fauna and the Ukolnoi Island Bear Lake faunule shows significant species-level differences that reflect differences in age, paleogeography, and paleoenvironment. Among the ten Ukolnoi Island mollusks identified to species only three, *Mya (Mya) truncata*, *Fusitriton oregonensis*, and *Natica (Cryptonatica) clausa*, are known in the Tachilni fauna of 53 taxa. In addition, three genera (*Pitar*?, *Penitella*, and *Thracia*) in the relatively small Ukolnoi Island faunule are not present in the Tachilni fauna.

The younger age of the Tachilni fauna accounts for the absence of the earliest middle Miocene *Turritella (Hataiella) sagai* that is abundant in the Ukolnoi Island Bear Lake faunule. However, most Ukolnoi Island species occur in both middle and late Miocene Bear Lake faunas (based on USGS collections), so their absence from the Tachilni fauna is probably due to a combination of paleogeographic and paleoenvironmental factors. Bear Lake sediments evidently accumulated in a semi-enclosed embayment opening onto Bristol Bay, analogous to, but much larger than, the modern Hendeen Bay–Port Moller and Port Heiden embayments (Nilssen, 1985) (Fig. 2). Based on differences in molluscan composition between the Tachilni and Bear Lake faunas, Tachilni sediments were evidently deposited along a relatively open coastline rather than in an embayment. The much less silty nature of the Tachilni sandstone matrix supports this inter-

pretation. Based on their relatively high content of volcaniclastic sediments, strata of the Unga Conglomerate Member are thought to be separable from other Bear Lake strata (Robert Detterman, written communication, 1987). The conspicuous absence from the Tachilni fauna of *Mytilus (Plicatomytilus) gratacapii*, the attached shoreline-dwelling bivalve that is present (and sometimes abundant) virtually throughout the Bear Lake Formation, suggests either greater water depth for the Tachilni fauna or the lack of a suitable hard substrate for the attachment of *M. (P.) gratacapii*. The inferred paleobathymetry of the Tachilni molluscan fauna, 20 to 50 m (Marincovich, 1983), is very similar to that of the Ukolnoi Island faunule and other Bear Lake faunules, so lack of a suitable hard substrate may account for the absence of *M. (P.) gratacapii* from the Tachilni fauna.

SYSTEMATIC PALEONTOLOGY

Taxonomic comments and abbreviated synonymies are given for all taxa. The synonymies include original citations and the subsequent citations that deal with the species most extensively. Abbreviations used are:

USGS M: U.S. Geological Survey, Branch of Paleontology and Stratigraphy, Menlo Park, California, Cenozoic locality number.

USNM: National Museum of Natural History, Washington, D.C.

Phylum Mollusca

Class Bivalvia

Family Nuculidae

Acila sp. indet.

One incomplete specimen of *Acila* was found on the mainland at M8329, and another on Ukolnoi Island at M7152. The M8329 specimen preserves no dentition, but shows that the species is large (at least 22 mm high), and the M7152 specimen consists only of an incomplete half of a hinge plate with 12 large, coarse teeth. No sculpture is preserved. An as yet unidentified, but large and coarse-toothed *Acila* does occur elsewhere in some Bear Lake outcrops (Marincovich, unpublished data, 1987). In addition, *Acila (Truncacila) empirensis* Howe, 1922, and *A. (T.) ermani* (Girard, 1843) are present on the Alaska Peninsula in the early late Miocene fauna of the Tachilni Formation (Marincovich, 1983) and both are similar in size and dentition to the present species. Also similar are two species questionably reported from the underlying Paleogene Stepovak Formation by MacNeil (in Burk, 1965), *A. (T.) shumardi* (Dall, 1909), and *Acila (Acila) gettysburgensis* (Reagan, 1909). Additional specimens from Ukolnoi Island or M8329 are needed to identify this species. The present specimens are not suitable for illustration. A

depth range of 5–200 m is given for the single living *Acila* (*Truncacila*) in the northeastern Pacific by Bernard (1983).

Family Nuculanidae

Yoldia sp. indet.

Figure 16

A single specimen of *Yoldia* was found on Ukolnoi Island and consists of an internal mold of one valve bearing a few fragments of shell material. Neither dentition nor exterior features of the shell are visible. In view of the large number of *Yoldia* species known from North Pacific Neogene faunas (Gladenkov, 1972), it is not possible to identify this specimen to species. The only previous report of a Neogene *Yoldia* species on the Alaska Peninsula is *Yoldia* (*Cnesterium*) *scissurata* Dall, 1897, from the Tachilni Formation of early late Miocene age (Marincovich, 1983). However, differences in shell outline alone are great enough to distinguish that species from the present one. The genus ranges throughout the Cenozoic and lives in a wide variety of modern environments in depths from the intertidal zone to 2,000 m (Keen and Coan, 1974).

Family Mytilidae

Mytilus (*Plicatomytilus*) *gratacapii* Allison and Addicott, 1976

Figure 3

Mytilus (*Plicatomytilus*) *gratacapii* Allison and Addicott, 1976: 9–13; pl. 2, figs. 1, 3, 6–10; pl. 3, figs. 1, 3, 5, 7, 8.

This mytilid is known only from the Bear Lake Formation, and the Ukolnoi Island specimens represent its oldest known occurrence. Only a single articulated and closed but incomplete individual and several fragments are present in the Ukolnoi Island faunule. However, the relatively short and thick shell with strongly arched anteroposterior axis, sinuous commissure, and irregular constrictions parallel to the growth lines are unmistakable features of this species.

This mytilid was first reported (as “*Mytilus middendorffi*”) from the “upper part” of the “basal fifth” of the Bear Lake Formation by Burk (1965), who defined this “basal fifth” as the Unga Conglomerate Member of the formation (Burk, 1965, p. 116). The stratigraphic range of this species was later extended upward into “the middle part of the [Bear Lake] formation” by Allison and Addicott (1976, p. 11), who considered that “the probability is that much, if not all, of the range zone of *M. gratacapii* is of late Miocene age.” Tenuous correlations between some Unga Conglomerate Member mollusks and faunas in Oregon and Washington suggested to Allison (1978) a possible middle Miocene age for some marine beds assigned to the Unga Conglomerate Member that contain *M. (P.) gratacapii*. The recognition of *M. (P.) gratacapii* here, in the Ukolnoi Island faunule of earliest middle Miocene age, at about 15–16 Ma (Marincovich and Kase,

1986), provides the earliest and only well-dated record of the species.

The habitat inferred for *M. gratacapii* by Allison and Addicott (1976) is in the intertidal to very shallow subtidal range, probably on exposed coastlines where its very thick shell was an adaptation to high-energy wave conditions. This inference remains to be reconciled with the interpretation of Nilsen (1985) that Bear Lake sediments were deposited in a semi-enclosed embayment.

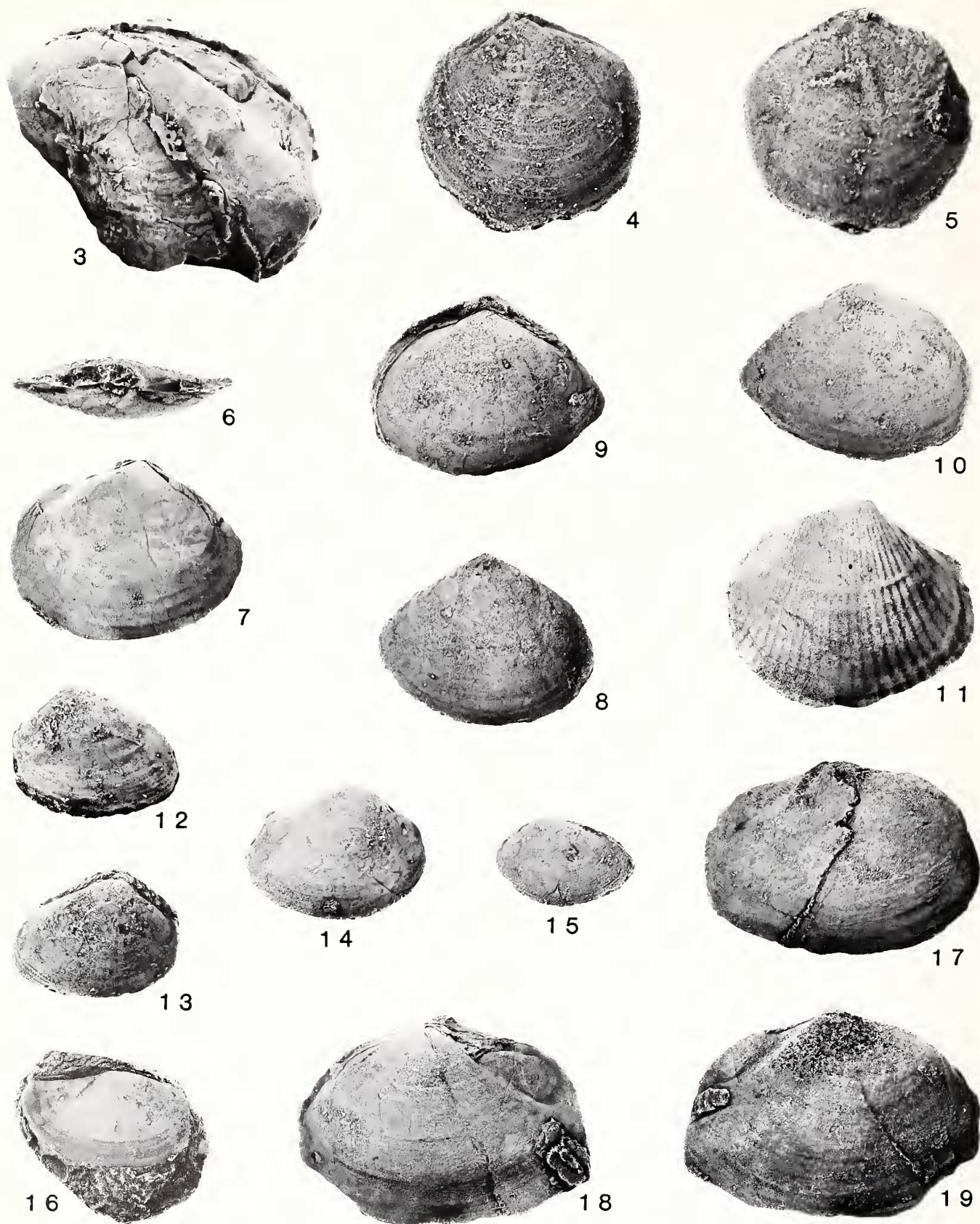
Family Lucinidae

Lucinoma acutilineata (Conrad, 1849)

Figures 4, 5

Lucina acutilineata Conrad, 1849:725, pl. 18, figs. 2, 2a, b. *Lucinoma acutilineata* (Conrad). Moore, 1964:70–71, pl. 15, figs. 7–10, 12. Marincovich, 1980:8, figs. 15, 16.

Among the most common bivalves in the Ukolnoi Island faunule, this species is recognized by its nearly circular outline, and by its regularly spaced, fine, and distinctly raised concentric lamellae that are separated by wider interspaces. Nearly all Ukolnoi Island specimens are articulated and closed, as is generally true for other eastern Pacific occurrences. The first eastern Pacific appearance of this species, in the Eugene Formation of Oregon (Hickman, 1969), has been assigned to the late Eocene and early Oligocene part of the Galvinian Stage by Armentrout (1975). Its youngest verified North American record is in the Astoria Formation of Oregon (Moore, 1964), in a fauna assigned to the Newportian Stage of late early Miocene through middle Miocene age (Addicott, 1981). However, this species has been tentatively identified in the Empire Formation (restricted) at Cape Blanco, Oregon, which has been assigned a late Miocene (Wishkahan Stage) age (Addicott, 1983). The only previous report of *L. acutilineata* from Alaska is in a Newportian molluscan fauna of the Topsy Formation in southeastern Alaska (Marincovich, 1980). Its modern homologue, *L. annulata* (Reeve, 1850), ranges from southern Alaska to Baja California, Mexico, in depths of 20 to 800 m, but is most common in the inner sublittoral zone (0–100 m) (Burch, 1944); it also occurs in Pliocene and Quaternary faunas (Addicott, 1973). Differences in shell morphology between *L. acutilineata* and *L. annulata* have been detailed by Stewart (*in* Tegland, 1933) and by Moore (1964). Grant and Gale (1931) considered *L. annulata*, as well as *L. columbiana* (Clark and Arnold, 1923) from upper Oligocene or lower Miocene strata of the Sooke Formation, British Columbia, Canada, to be synonyms and thought *L. hannibali* (Clark, 1925) to be very closely related. Addicott (1976) similarly thought that specimens figured as *L. hannibali* by Tegland (1933) from lower Oligocene beds of the Blakeley Formation in Washington, were probably *L. acutilineata*. Slodkewitsch (1938a, b) and later Russian workers (e.g., Devyatilova and Volobueva, 1981) considered *L. annulata*, *L. hannibali*, and *L. columbiana* to be synonyms



of *L. acutilineata*. *Lucinoma acutilineata* and *L. annulata* are considered to be separate species herein. However, a study to establish the taxonomic relationships of these and related species is needed.

East Asian faunas containing *L. acutilineata* have been cited in Japan, Sakhalin, and Kamchatka. The species has been reported in numerous Japanese Miocene formations, as well as in some Oligocene and Pliocene strata (Hatai and Nisiyama, 1952; Masuda and Noda, 1976; Masuda, 1984). The Pliocene occurrences may be assignable to *L. annulata*. The Japanese occurrences of this species are so numerous that determining their validity and age range is beyond the scope of this study. Slodkewitsch (1938a, b) reported this species in the lower part of the Tighil Group, in the Vayampol Group, and in the upper portion of the "Clayey-sandstone Formation" of Kamchatka, as well as in the Mayamraf, Rykhlaya, and Khoi formations and in the lower part of the Machigar Formation of Sakhalin. However, age assignments of these Far Eastern U.S.S.R. Tertiary strata are uncertain owing to the lack of detailed biostratigraphic studies. The oldest record cited for *L. acutilineata* in the modern Russian literature is in the Olkhov Group of the Koryak Uplands, which has been assigned a late Eocene age (Devyatilova and Volobueva, 1981). This occurrence is coeval in part with, or possibly older than, that in the Eugene Formation of Oregon, noted above.

Family Tellinidae

Macoma sp. indet.

Figures 6–10

This bivalve is abundant on Ukolnoi Island, with all specimens articulated and closed, but it is preserved largely as external casts. As a result, internal features of the shell are not well preserved and a species determination is not possible. This species is characterized by its centrally located, relatively high umbones. The posterior end is only slightly elongated, narrowly to moderately rounded but not pointed, and bent slightly to the right; the anterior end is more broadly rounded. The anterior dorsal margin is slightly convex, and the posterior dorsal margin is slightly concave or, less commonly, straight. Both valves are moderately inflated. Average

dimensions are: length 50 mm, height 40 mm, thickness (articulated) 15 mm.

Alaska Peninsula Miocene *Macoma* identified to species have been previously reported from faunas of the Bear Lake Formation (but not the Unga Conglomerate Member) and the Tachilni Formation. *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923) was cited from one outcrop of the Paleogene Belkofski Formation by Marincovich and McCoy (1984), but that outcrop is now considered to belong to the Bear Lake Formation (Frederic Wilson, oral communication, 1987). MacNeil (*in* Burk, 1965, p. 228) reported *Macoma* cf. *M. calcarea* (Gmelin, 1791) from the type section of the Bear Lake Formation, and Marincovich (*in* Detterman and others, 1981) reported *M. (M.)* cf. *M. (M.) astori* Dall, 1909, *Macoma incongrua* (von Martens, 1865), and *M. (M.) optiva* (Yokoyama, 1923) from the same section. Marincovich (1983) reported *M. (M.)* cf. *M. (M.) astori*, *M. (M.) optiva*, and *M. incongrua* from the type section and other sections of the Tachilni Formation. Of these species, *M. (M.)* cf. *M. (M.) astori* is most similar in shape to the Ukolnoi Island species, but clearly differs from the latter by having its umbones set closer to the posterior end, by its somewhat subtruncate posterior termination, and by the presence of a shallow groove just below the posterior dorsal margin. *Macoma* species illustrated from Neogene faunas of the eastern Gulf of Alaska, in the Yakagata and Topsy formations (Clark, 1932; Kanno, 1971; Marincovich, 1980), are dissimilar in form to the Ukolnoi Island taxon.

In view of the many *Macoma* species that have been described from Japanese, Russian, and western North American Neogene faunas, and the imperfect preservation of the Ukolnoi Island specimens, there is little chance of an accurate species-level identification based on these specimens. Living species of *Macoma* dwell in such a wide variety of habitats that this taxon is not useful for inferring paleoecology.

Family Cardiidae

Clinocardium sp. indet.

Figure 11

Two external casts of articulated, closed specimens of *Clinocardium* at M8331 (= M7152) are too poorly preserved

Figures 3–19. *Mytilus* (*Plicatomytilus*) *gratacap*i Allison and Addicott, *Lucinoma acutilineata* (Conrad), *Macoma* sp. indet., *Clinocardium* sp. indet., *Pitar?* sp., *Yoldia* sp. indet., *Thracia* sp. indet. **Fig. 3.** *Mytilus* (*Plicatomytilus*) *gratacap*i Allison and Addicott. USNM 418379, USGS loc. M7153; length 66 mm, height 51.5 mm. **Figs. 4, 5.** *Lucinoma acutilineata* (Conrad). USNM 418380, USGS loc. M7154; height 20 mm, length 20.7 mm, thickness (both valves) 8.1 mm. **4.** Right valve. **5.** Left valve. **Figs. 6–10.** *Macoma* sp. indet. **6, 7.** USNM 418381, USGS loc. M8331; length 43.6 mm, height 36.4 mm, thickness (both valves) 12.6 mm. **6.** Dorsal view. **7.** Left valve. **8.** USNM 418382, USGS loc. M7154; length 39.2 mm, height 32.3 mm, thickness (both valves) 11.8 mm. **Right valve.** **9, 10.** USNM 418383, USGS loc. M7154; length 44 mm, height 35.1 mm, thickness (both valves) 12.3 mm. **9.** Left valve. **10.** Right valve. **Fig. 11.** *Clinocardium* sp. indet. USNM 418384, USGS loc. M8331; length 46 mm, height (incomplete) 40 mm, thickness (both valves) 22.8 mm. **Figs. 12–15.** *Pitar?* sp. USNM 418385, USGS loc. M7154; length 32.3 mm, height 25.5 mm, thickness (both valves) 13.5 mm. **12.** Left valve. **13.** Right valve. **14.** USNM 418386, USGS loc. M8331; length 34.1 mm, height 26 mm, thickness (both valves) 14.9 mm. **Right valve.** **15.** USNM 418387, USGS loc. M8331; length 26.6 mm, height 18.7 mm, thickness (both valves) 10.8 mm. **Left valve.** **Fig. 16.** *Yoldia* sp. indet. USNM 418388, USGS loc. M8331; length (incomplete) 31.4 mm, height 18.8 mm. **Figs. 17–19.** *Thracia* sp. indet. **17.** USNM 418389, USGS loc. M7153; length 51.6 mm, height 38.4 mm, thickness (both valves) 17.2 mm; **right valve.** **18.** USNM 418390, USGS loc. M7153; length 55.8 mm, height 40.5 mm, thickness (both valves) 17.1 mm, **left valve.** **19.** **Right valve.**

for specific identification. One valve of the best preserved specimen bears about 30 closely spaced, low and rounded radial costae and the matching valve shows a centrally placed, somewhat sharply elevated umbo. Each imperfectly preserved specimen is about 40 to 45 mm high and slightly longer than high. The only Miocene clinocardiums previously described and illustrated from the Alaska Peninsula occur in the Tachilni Formation (Marincovich, 1983) and include: *C. cf. C. ciliatum* (Fabricius, 1780), *C. hannibali* Keen, 1954, *C. meekianum* (Gabb, 1866) new subspecies?, and *C. cf. C. pristinum* Keen, 1954. These four Tachilni taxa differ distinctly in either size, shape, or rib-count, or in all three characters, from the Ukolnoi Island taxon. *Clinocardium* species known from Miocene faunas of the Yakataga Formation in the eastern Gulf of Alaska (Kanno, 1971) include: *C. yakatagense* (Clark, 1932), *C. brooksi* (Clark, 1932), and *C. hopkinsi* Kanno, 1971. These Yakataga species also clearly differ in size, shape, or rib-count from the Ukolnoi Island specimens.

Clinocardium is widespread in North Pacific Cenozoic faunas and lives in depths from the intertidal zone to 200 m in the northeastern Pacific (Keen and Coan, 1974).

Family Veneridae

Pitar? sp.

Figures 12–15

?Pitar sp. Marincovich, in Detterman and others, 1981: sheet 2, table 1.

Three individuals of this taxon occur on Ukolnoi Island, but are too poorly preserved as external casts for certain generic placement. The shell outlines are subtriangular, with somewhat narrowly rounded posterior ends and more broadly rounded anterior ends. The best preserved specimen has articulated, closed valves and is 32.3 mm long, 25.5 mm high, and 13.5 mm thick (Figs. 12, 13). Remnants of fine, closely and evenly spaced concentric costae are the only visible sculpture. The other two specimens are similar in size and their sculpture is identical, but less well preserved. Interior features of *Pitar?* sp. are not visible.

Two specimens identical to these were reported as “*?Pitar* sp.” by Marincovich (in Detterman and others, 1981) from the type section of the Bear Lake Formation. Those specimens also are preserved as external casts.

This taxon belongs within the venerid subfamily Pitarinae, in which most genera are associated with mild-temperate to tropical fossil and modern faunas. Numerous Paleogene *Pitar* (as well as the very closely related genus *Macrocallista* that is indistinguishable from *Pitar* in many North Pacific fossil faunas) are known from faunas in Oregon and Washington (Weaver, 1943), as well as from Japan (Hatai and Nisiyama, 1952; Masuda and Noda, 1976) and the Far Eastern U.S.S.R. (Devyatilova and Volobueva, 1981). Paleogene *Pitar* species also occur in southern Alaska, in the Stepovak Formation of the Alaska Peninsula (Dall, 1904) and in the Poul Creek Formation (Kanno, 1971) in the eastern Gulf of Alaska. However, there seem to be no verified pitars in high-latitude

North Pacific Neogene deposits (Roth, 1975), making the identity of the Ukolnoi Island genus all the more intriguing. *Pitar?* sp. is considered here to be an extralimital western Pacific warm-water element in the Ukolnoi Island fauna.

Family Myidae

Mya (*Mya*) *truncata* Linnaeus, 1758

Figures 26, 27

Mya truncata Linnaeus, 1758:670. Fujie, 1957a:399–400, pl. 3, figs. 1–4.

Mya (*Mya*) *truncata* Linnaeus. Grant and Gale, 1931:414–415. MacNeil, 1965:38–40, pl. 8, figs. 1–12; pl. 9, figs. 1–3, 5–20.

This distinctive bivalve is present at M8329 on the Alaska Peninsula mainland (Fig. 2) as well as on Ukolnoi Island. The best preserved specimens have characteristically ovate shells with coarse, irregular growth lines as the only sculpture, and sharply truncated posterior ends. All specimens studied herein have articulated, closed valves, but their orientation at the outcrops (i.e., whether in living positions or not) was not observed. Opinions vary about the earliest appearance of this species. MacNeil (1965) cited this species in the lower part of the Yakataga Formation in the eastern Gulf of Alaska and in the Takinoue (= Chikubetsu) Formation of Hokkaido, and considered both occurrences to be of early middle Miocene age. Strauch (1972) considered its first appearance to be in late Miocene faunas of the northeastern Pacific. The present Alaska Peninsula specimens, of earliest middle Miocene age, support MacNeil's (1965) opinion, and are among the earliest known examples of *M. (M.) truncata* in Alaska or elsewhere.

Stratigraphic occurrences of this species are too numerous to list. MacNeil (1965) noted Miocene and Pliocene records extending from northern Honshu to southern California, and late Pliocene and Pleistocene records in the Arctic and North Atlantic oceans. He thought that its abrupt appearance in Alaska suggested an origin in eastern Asia (MacNeil, 1965, p. 39). Stratigraphic records from Japan (Nagao and Inoue, 1941; Fujie, 1957a, b) are not detailed enough to decide this issue. The Russian literature cites pre-middle Miocene occurrences of *M. (M.) truncata* in faunas of the late early Miocene Ilyin Stage of West Kamchatka, in the Eliseev Formation fauna assigned to the early early Miocene Kuluven Stage of the Lower Anadyr Basin, and the in the early Miocene Undal-Umen Formation of the Koryak Uplands (Devyatilova and Volobueva, 1981). Unfortunately, the only early Miocene specimen figured by Devyatilova and Volobueva (1981, pl. 38, fig. 8), from the Undal-Umen Formation, lacks a truncated posterior end and is likely assignable to another species. The ancestors and earliest individuals of *M. (M.) truncata* perhaps do occur in the Far Eastern U.S.S.R., but the plethora of morphologically overlapping *Mya* species described from that region (Slodkewitsch, 1938a, b; Krishtofovich and Ilyina, 1954; Ilyina, 1963; Zhidkova, 1972; Devyatilova and Volobueva, 1981; Menner, 1984), including

some with widely varied degrees of posterior truncation, preclude an easy settling of this matter.

This is a shallow-water species in modern seas. The accepted depth range for eastern Pacific *Mya* is 0–50 m (Keen and Coan, 1974), although depths to over 100 m are claimed (Bernard, 1979, 1983). *Mya* (*Mya*) *truncata* is most abundant in cool-temperate to frigid habitats, but also ranges into waters as warm as mild-temperate. It is a common Arctic Ocean species whose modern southern range end-points are northern Honshu and possibly northern California in the Pacific, and Cape Cod and the Mediterranean in the Atlantic (Bernard, 1979).

Mya sp. indet.

Figures 23–25

Ukolnoi Island *Mya* specimens clearly differ from *M. (M.) truncata* by having moderately produced, untruncated posterior terminations with only slight gapes. They differ also from the next most common Alaskan Miocene *Mya*, *M. (M.) cuneiformis* (Böhm, 1915), by lacking a strongly beveled posterodorsal margin, by being thicker in section, and by lacking evidence of irregular raised wrinkles that are distinctive features of all other Alaskan shells of this species that I have seen. Both specimens of *Mya* sp. indet. have articulated and closed valves. Their shapes fall within a morphologic spectrum that includes a large number of previously described North Pacific Miocene *Mya*. References to works illustrating specimens similar to *Mya* sp. indet. are noted in the above discussion of *M. (M.) truncata*, and in a discussion by Marincovich (1983) of *Mya* new species? from the Tachilni Formation.

Family Pholadidae

Penitella sp. indet.

Figures 20–22

This bivalve is present at M7153 on Ukolnoi Island, although poor preservation does not allow identification of the species. However, the elongate-oval shell, distinct umbonal-ventral sulcus, with the anterior end closed by a callum, and the dorsal extension of the callum extending from the beaks to the umbones place this species in *Penitella*. The mesoplax, one of the most diagnostic features in the genus, is missing from all specimens. These specimens are the only penitellas reported from the Bear Lake Formation. Of the eight species of Cenozoic *Penitella* noted in the northeastern Pacific by Kennedy (1974), the oldest is of Oligocene age, but none is known in Alaska except in Pleistocene and Holocene faunas. Northwestern Pacific Cenozoic Pholadidae have not been monographed, so the taxonomy and stratigraphic distribution of species there are still uncertain. As noted by Kennedy (1974, p. 40) for northeastern Pacific pholads, fossils often have been assigned to the Pliocene to Holocene species *Penitella penita* (Conrad, 1837), more for convenience than from conviction. The oldest such record is from the Khulgun Formation of the Tighil Group in West Kamchatka (Slodke-

witsch, 1938a, b), in strata of inferred Paleocene through middle Eocene age (Krishtofovich, 1947; Menner and others, 1977). *Penitella* is also reported in Oligocene and younger faunas in Japan (Hatai and Nisiyama, 1952; Kennedy, 1974; Masuda and Noda, 1976). The Ukolnoi Island specimens definitely are not *P. penita* (G.L. Kennedy, written communication, 1987).

Most pholads, including *Penitella*, inhabit the high inner sublittoral to intertidal zones and are good indicators of shallow water and the presence of a nearby shoreline (Kennedy, 1974). Modern *Penitella* are typically rock borers, but most middle Tertiary records are from sediments that may have been hardened by compaction rather than by cementation (G.L. Kennedy, written communication, 1987). The burrows of Ukolnoi Island specimens are filled with matrix identical to that of the surrounding sediment. In such a case, it is inferred that sediment deposition was contemporaneous with the boring activity of the pholad (Kennedy, 1974, p. 19). Because this species is abundant at M7153, this Ukolnoi Island locality probably was at or very close to a shoreline.

Family Thraciidae

Thracia sp. indet.

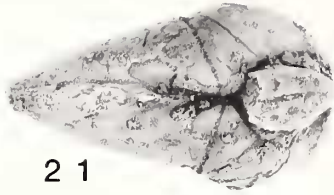
Figures 17–19

This species is represented on Ukolnoi Island by five articulated and closed specimens whose average size is: length 52 mm, height 38 mm, and thickness (both valves) 17 mm. The umbo is central and narrowly elevated, and the anterior dorsal margin is convex with a broad break in slope at its midpoint that adds a blocky appearance to the shell. The posterior dorsal margin is concave, especially near the umbo. The posterior truncation is only slightly oblique, and is nearly normal to the long axis of the shell; the posterior ventral corner of the shell juts out only slightly farther than the posterior dorsal corner. The depressed area along the posterior dorsal margin, which is characteristic of the genus, is prominent and set off from the main part of the shell by a low angulation that radiates from the umbo to the posterior ventral corner of the shell. All specimens are preserved as internal molds with small remnants of shell material along the dorsal margins. Some muscle scars, but no pallial lines, are preserved.

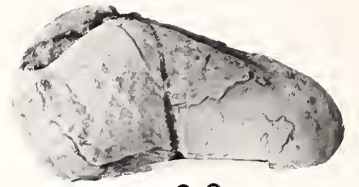
Thracia has not been reported previously from the Bear Lake Formation. The shell form of this species resembles that of *Periploma* (*Periploma*) cf. *P. (P.) alantica* (Krause, 1885) from lower upper Miocene strata of the Tachilni Formation (Marincovich, 1983). As I noted at that time, the Tachilni *Periploma* is nearly identical in form to *Thracia*, but was placed in *Periploma* owing to the presence of a chondrophore with an internal buttress and a nacreous interior shell layer. These features are not evident in the Ukolnoi Island specimens, perhaps due to imperfect preservation. The principal basis for assigning the present specimens to *Thracia* is shell form. Because there are at least 25 nominal *Thracia* species described from North Pacific Tertiary faunas (Keen and Bentson, 1944; Kamada, 1955; Masuda and Noda, 1976;



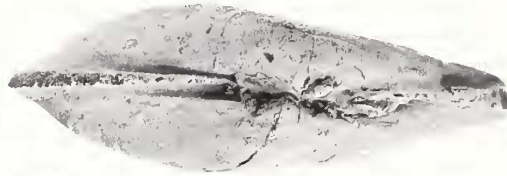
20



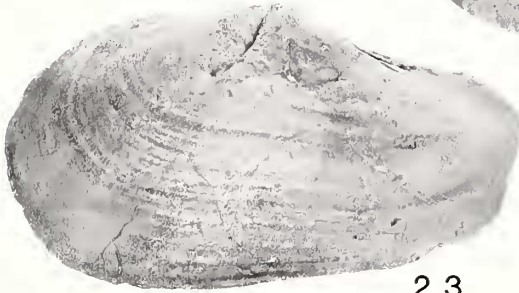
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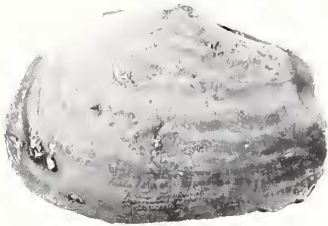
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33

Devyatilova and Volobueva, 1981), with considerable morphological variation shown by some, assignment of the present imperfectly preserved specimens to a species is not possible.

Modern northeastern Pacific *Thracia* species dwell in nesting habitats in depths from the intertidal zone to 135 m (Keen and Coan, 1974).

Class Gastropoda

Family Turritellidae

Turritella (Hataiella) sagai

Kotaka, 1951

Figures 28–33

Turritella s-hataii sagai Kotaka, 1951:87–88, pl. 12, figs. 13–17.

Turritella (Hataiella) sagai Kotaka. Kotaka, 1959:89–91, pl. 9, figs. 6–8, 10, 12, 18. Marincovich and Kase, 1986:61–65, figs. 2a–h.

This chronostratigraphically important species is the principal basis for assigning an earliest middle Miocene age (15–16 Ma) to the Bear Lake strata on Ukolnoi Island (Marincovich and Kase, 1986). This turritellid occurs in prolific numbers at Ukolnoi Island outcrops, where it is always accompanied by the equally abundant scaphopod *Dentalium (Rhabdus)* cf. *D. (R.) schencki* Moore, 1964.

In addition to the three Ukolnoi Island localities cited for this species by Marincovich and Kase (1986), a fourth Alaskan occurrence of this species, and the first on the Alaska Peninsula mainland, at M8329 (Fig. 2), was recognized during the present study.

Japanese occurrences of *T. (H.) sagai* are in warm-temperate to subtropical, inner shelf faunas (Kotaka, 1959). The age range of this species (15–16 Ma) coincides with the peak of the earliest middle Miocene climatic warming in the North Pacific (Savin and others, 1981), and the migration of *T. (H.) sagai* from Honshu to southwestern Alaska evidently occurred during that brief interval (Marincovich and Kase, 1986). The anomalous presence of this warm-water species in the otherwise cool-temperate Ukolnoi Island faunule is discussed earlier herein. Modern *Turritella* species in the northeastern Pacific live in depths of 20 to 185 m (Keen and Coan, 1974) and are most abundant in the upper parts of their depth ranges. The prolific occurrence of *T. (H.) sagai*

supports an inferred shallow inner shelf habitat for the Ukolnoi Island faunule.

Family Naticidae

Natica (Cryptonatica) clausa

Broderip and Sowerby, 1829

Figure 34

Natica clausa Broderip and Sowerby, 1829:372.

Natica (Cryptonatica) clausa Broderip and Sowerby. Marincovich, 1977:410–418, pl. 41, figs. 7–10; pl. 42, figs. 1–6. Marincovich, 1983:113, pl. 22, fig. 21.

An umbilicus completely closed by a semicircular umbilical callus, together with a globose shell having a moderately elevated spire, characterize this species, which is the most abundant naticid in Alaskan Tertiary deposits. A summary of this species' morphological variation and stratigraphic occurrences is given in Marincovich (1977). The oldest known specimens come from upper Oligocene or lowermost Miocene strata of the Narrow Cape Formation on Sitkinak Island (Fig. 1), western Gulf of Alaska (Allison and Marincovich, 1982), and the species is ubiquitous in Miocene to Holocene cool-temperate to cold-water North Pacific faunas. The oldest well-documented record of this species in the western Pacific is in the latest early Miocene and early middle Miocene faunas of the Takinoue and Furanui formations of Hokkaido (Majima, 1984). Occurrences in presumed early Miocene faunas of Sakhalin (Ilyina in Krishtofovich and Ilyina, 1954) and the Koryak Uplands (Devyatilova and Volobueva, 1981) are not well dated. In modern seas this species dwells in depths of 9–970 m, in progressively greater depths from north to south (Marincovich, 1977), so it is useful as an indicator of cool or cold water. Where it occurs with shallow-water mollusks of somewhat warmer water aspect, as in the Ukolnoi Island faunule, this species is evidence for the possible occurrence of upwelling cool water.

Family Cymatiidae

Fusitriton oregonensis (Redfield, 1846)

Figures 41, 42

Triton oregonense Redfield, 1846:163–168, pl. 11, figs. 2a, b.

Fusitriton oregonensis (Redfield). Smith, 1970:485–497, pl.

←
Figures 20–33. *Penitella* sp. indet., *Mya* sp. indet., *Mya (Mya) truncata* (Linnaeus), *Turritella (Hataiella) sagai* Kotaka. **Figs. 20–22.** *Penitella* sp. indet. USNM 418391, USGS loc. M7153; length 43.3 mm, height 24.1 mm, thickness (both valves) 24.2 mm. **20.** Left valve. **21.** Dorsal view. **22.** Right valve. **Figs. 23–25.** *Mya* sp. indet. USNM 418392, USGS loc. M8331; length 70 mm, height 40 mm, thickness (both valves) 23.1 mm. **23.** Left valve. **24.** Dorsal view. **25.** Right valve. **Figs. 26, 27.** *Mya (Mya) truncata* Linnaeus. USNM 418393, USGS loc. M8331; length 44.7 mm, height 30.3 mm, thickness (both valves) 28.6 mm. **26.** Left valve. **27.** Right valve. **Figs. 28–33.** *Turritella (Hataiella) sagai* Kotaka. **28.** USNM 418394, USGS loc. M7153; length 54.7 mm, diam. 17.1 mm. **29.** USNM 418395, USGS loc. M7152; length 43.1 mm, diam. 18.5 mm. **30.** USNM 418396, USGS loc. M7152; length 44.1 mm, diam. 16.7 mm. **31.** USNM 418397, USGS loc. M8331; length 47.4 mm, diam. 15.8 mm. **32.** USNM 418398, USGS loc. M7152; length 66.2 mm, diam. 17.0 mm. **33.** USNM 418399, USGS loc. M7152; length 79.2 mm, diam. 16.8 mm.

45, figs. 1–11; pl. 46, figs. 1, 2, 5, 6, 8, 13, 14; pl. 47, figs. 2, 3. Marincovich, 1983:114–116, pl. 23, fig. 1.

This species is represented in the Ukolnoi Island faunule by a single specimen bearing only traces of shell sculpture. However, the presence of low, flat-topped costae separated by much narrower interspaces, as well as internal molds of coarse and unevenly spaced axial varices are reliable bases for identification. This sculpture falls within the broad limits described for this species by Smith (1970). Although present in temperate Miocene to Holocene faunas across the North Pacific margin, *F. oregonensis* is relatively uncommon in Alaskan Miocene deposits. Its only previous record on the Alaska Peninsula is from the type locality of the Tachilni Formation at Cape Tachilni (Fig. 2), in a fauna of early late Miocene age (Marincovich, 1983). All other Alaskan records are from the eastern Gulf of Alaska, where this species is reported in upper lower(?) or middle Miocene (Newportian Stage) strata of the Topsy Formation (Marincovich, 1980) and in lower middle Miocene (Newportian Stage) deposits of the Yakataga Formation (Smith, 1970; Arey, 1978). The oldest verified occurrence outside Alaska is in lower upper Miocene (Wishkahan Stage) strata of the Empire Formation at Coos Bay, Oregon (Dall, 1909). Questionable Miocene occurrences noted in Japan by Smith (1970) have been assigned Pliocene ages by Masuda and Noda (1976). Numerous Pliocene and Pleistocene records ranging from central Japan to southern California are given by Smith (1970). Thus, the Ukolnoi Island specimen represents one of the oldest occurrences of *F. oregonensis* and reinforces the idea that this species evolved in southern Alaska.

Individuals of *F. oregonensis* live in temperate to cold waters of the North Pacific, ranging from central Honshu, Japan, to southern California (Smith, 1970). This species has been observed in the intertidal zone from southeastern Alaska to Puget Sound, Washington, but has also been reported in depths as great as 2,370 m (Smith, 1970). It has been collected in temperatures of 7–11°C in Puget Sound and in temperatures less than 8°C off southern California (Valentine and Emerson, 1961). This species has been reported in progressively greater depths south of Puget Sound and southwestward of the Bering Sea, probably in response to deepening isotherms (Smith, 1970).

Family Buccinidae

Colus? sp.

Figure 40

A single Ukolnoi Island specimen from M8331 may be a juvenile of *Colus* sp. It is 29 mm in height and consists largely of an internal mold. The spindle shape, slightly elongate anterior canal, and absence of columellar folds suggests possible placement in *Colus*. The presence of a small bryozoan colony at a location that was once within the anterior canal suggests that this shell lay on the sea bottom for some time before burial.

Questionably identified *Colus* has been reported before from the type section of the Bear Lake Formation (MacNeil

in Burk, 1965; Marincovich in Detterman and others, 1981), and *Colus* aff. *C. spitzbergensis* (Reeve, 1855) has been cited from the same stratigraphic section (Marincovich in Detterman and others, 1981). The Ukolnoi Island specimen lacks any trace of its original exterior surface, so its relationship to *C. spitzbergensis*, which has strong spiral sculpture, is problematical.

Family Neptuneidae

Neptunea (*Neptunea*)

aff. *N. (N.) lyrata altispira* Gabb, 1869

Figures 35–38

Neptunea altispira Gabb, 1869:44–45, pl. 14, fig. 2.

Neptunea (*Neptunea*) *lyrata altispira* Gabb. Nelson, 1974: 111–118, pl. 2, figs. 3, 5; pl. 3, figs. 1–7; pl. 4, figs. 1–5; pl. 5, figs. 1–7. Marincovich, 1983:118–119, pl. 23, fig. 8.

Several specimens in the Ukolnoi Island faunule are similar to *N. (N.) lyrata altispira*, but differ in important features. Two individuals from M7153 have the general shape, size, and coarse spiral costae separated by slightly narrower interspaces that are features of *N. (N.) lyrata altispira*, but both clearly lack the secondary and tertiary spiral costellae within interspaces, and the sloping, slightly concave subsutural area of that subspecies. As treated in Nelson (1974), *N. (N.) lyrata altispira* ranges in age from late middle or early late Miocene to early or middle Pleistocene, with occurrences in numerous faunas extending from east-central Honshu to northern California. The oldest occurrence of this subspecies is in the lower part of the Yakataga Formation in the eastern Gulf of Alaska (Nelson, 1974), and its first appearance on the Alaska Peninsula is in the early late Miocene (Wishkahan Stage) fauna of the Tachilni Formation at Cape Tachilni (Marincovich, 1983), about 80 km southwest of Ukolnoi Island (Fig. 2). The *N. (N.) lyrata* substock of Nelson (1974) contains several subspecies and ranges in age from early Miocene to Holocene. Specimens with more completely preserved sculptural details are needed to confidently identify Ukolnoi Island specimens with one of these subspecies.

Beringius crebricostatus (Dall, 1902)

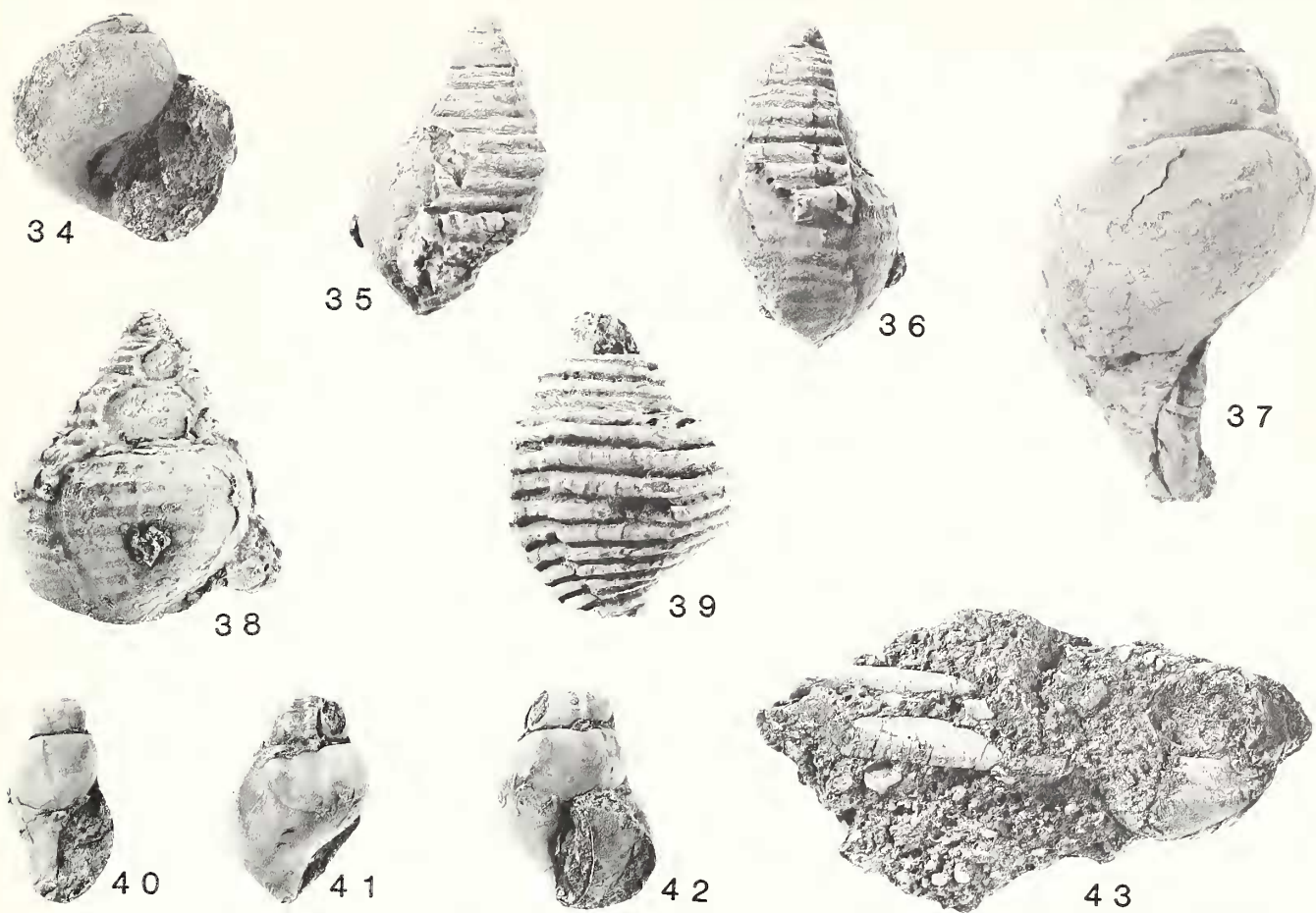
Figure 39

Chrysodomus crebricostatus Dall, 1877:1 [never published]. Dall, 1902:530, pl. 35, fig. 1.

Beringius cf. *B. crebricostatus* (Dall). Kanno, 1971:120–121, pl. 15, fig. 3.

Beringius aff. *B. crebricostatus* (Dall). MacNeil, 1973:120, pl. 10, figs. 1, 2.

This distinctive species is characterized by its coarse spiral costae that are commonly T-shaped in section, and by its lack of axial sculpture. There are only two published reports of this species in Alaskan Tertiary faunas: from the Unga Conglomerate Member at Cape Aliaksin, Alaska Peninsula (Fig. 2) (MacNeil, 1973; as “aff.”) and from the lower part of the Yakataga Formation at Cape Yakataga, eastern Gulf



Figures 34-43. *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby, *Neptunea* (*Neptunea*) aff. *N. (N.) lyrata altispira* Gabb, *Beringius* cf. *B. crebricostatus* Dall, *Colus*? sp., *Fusitriton oregonensis* (Redfield), *Dentalium* cf. *D. schencki* Moore. **Fig. 34.** *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby. USNM 418400, USGS loc. M7154; height 20.5 mm, diam. 15.8 mm; $\times 2$. **Figs. 35-38.** *Neptunea* (*Neptunea*) aff. *N. (N.) lyrata altispira* Gabb. **35-36, 38.** USNM 418401, USGS loc. M7153; height (incomplete) 45.3 mm. Showing spiral sculpture. **37.** USNM 418402, USGS loc. M7153; height 68.2 mm, diam. 40.0 mm. **Fig. 39.** *Beringius crebricostatus* Dall. USNM 418403, USGS loc. M8331; height 44 mm, diam. 34 mm. **Fig. 40.** *Colus*? sp. USNM 418404, USGS loc. M8331; height 28.7 mm, diam. 15 mm. **Figs. 41, 42.** *Fusitriton oregonensis* (Redfield). USNM 418405, USGS loc. M7154; height (incomplete) 30.3 mm, diam. (incomplete) 22.4 mm. **41.** Left side, showing remnant of spiral sculpture. **42.** Apertural view, showing varices. **Fig. 43.** *Dentalium* (*Rhabdus*) cf. *D. (R.) schencki* Moore. USNM 418406, USGS loc. M7152; larger specimen, length (incomplete) 31.7 mm, greatest diam. 6.4 mm.

of Alaska (Kanno, 1971; as "cf.") (Fig. 1). The Yakataga Formation occurrence may be of early or middle Miocene age (Kanno, 1971), whereas the Unga Conglomerate Member occurrence is of middle Miocene age (herein). Except for the present specimens and the uncertain Cape Aliaksin occurrence, this species is not present in the many Bear Lake Formation collections that have been made in recent years, including those from the formational type section near Bear Lake (Fig. 2) (Marincovich in Dettnerman and others, 1981). MacNeil (1973) noted that the range of morphologic variation in Holocene *B. crebricostatus* is based on very few specimens, including only one intact shell, the holotype. He further noted that although all known fossil specimens are imperfectly preserved, those from Cape Aliaksin and the lower part of the Yakataga Formation may comprise a sep-

arate species, compared to Holocene specimens, because they seem to have a more elongate anterior canal and lack a siphonal fasciole. Like these Miocene specimens mentioned by MacNeil (1973), Ukolnoi Island specimens have elongate anterior canals and lack siphonal fascioles.

The degree to which the coarse spiral costae are T-shaped in section varies considerably among individuals and also, to a lesser degree, on different portions of a single individual. The costae of some Ukolnoi Island specimens are deeply undercut above and below to form a characteristic "T" shape, whereas costae on other specimens are straight sided or inclined slightly to form a V-shaped interspace. Similar variations are shown on the holotype figured by Dall (1902) and Oldroyd (1927).

There are no reports of this species in east Asian fossil

faunas. Its modern geographic range is from Plover Bay, Far Eastern U.S.S.R., to the Aleutian Islands, the Shumagin Islands in the western Gulf of Alaska, and British Columbia, Canada (Foster, 1981) (Fig. 1). The holotype comes from a depth of 182 m at Unalaska Island, Aleutian Islands, Alaska (Fig. 1), and the species is reported to occur in depths of 300 to 600 m in British Columbia (Bernard, 1970), but fossil occurrences are in inner-shelf faunas. This evident difference in bathymetric preference between fossil and Holocene individuals may relate to the differences in shell morphologies noted by MacNeil (1973) and reinforces the idea of a possible taxonomic difference between fossil and modern specimens.

If Alaskan Miocene specimens are a different species from modern *B. crebricostatus*, then their occurrences on Ukolnoi Island, at Cape Aliaksin, and in the Cape Yakataga area suggest possible correlations. The inferred older parts of the Bear Lake Formation, on Ukolnoi Island and at Cape Aliaksin, may correlate with the stratigraphically lower part of the Yakataga Formation bearing this species. If so, the occurrence of this possibly extinct *Beringius* species may coincide with the climatic warm interval during which *Turritella* (*Hataiella*) *sagai* migrated from Japan to southwestern Alaska (Marincovich and Kase, 1986).

The work usually cited for the original description of this species, Dall (1877), was never published, and Dall's description was then available only as an unpublished preprint. The correct authorship for *B. crebricostatus* is Dall (1902), as noted by Boss and others (1968).

Tyrannoberingius rex Marincovich, 1981

Tyrannoberingius rex Marincovich, 1981:176, text-figs. 2a-e.

This species is represented on Ukolnoi Island by fragments that preserve parts of the penultimate and body whorl of one individual. These fragments exhibit the coarse axial sculpture and lack of spiral sculpture, narrowly channeled suture, and very thick shell wall that help to characterize *T. rex*. The only previous report of *T. rex* is from its type locality at Cape Aliaksin (Fig. 2) (Marincovich, 1981), in rocks assigned to the Unga Conglomerate Member of the Bear Lake Formation and thought to be of middle Miocene age (herein). Even though the age range of *T. rex* is not yet well documented, this species establishes a tentative and potentially important tie between the Bear Lake faunules of Ukolnoi Island and Cape Aliaksin. An andesite flow overlying the Unga Conglomerate Member sediments at Cape Aliaksin has yielded a potassium-argon age of 10.4 ± 0.49 Ma (Frederic Wilson, written communication, 1986). The inferred age of the Ukolnoi Island faunule is 15–16 Ma (Marincovich and Kase, 1986), based on the presence of *Turritella* (*Hataiella*) *sagai*. The Cape Aliaksin sequence is presumed herein to be somewhat younger, because it lacks *T. (H.) sagai* and because the base of this thick sequence is not exposed and must lie at least a short stratigraphic distance above the presumably underlying Stepovak Formation. The Cape Aliaksin faunule is inferred herein to fall in age between the Ukolnoi Island faunule at 15–16 Ma and the overlying Cape Aliaksin andesite flow at

10.4 ± 0.49 Ma, and to be of middle Miocene age. Further study of Bear Lake faunas from many localities will test the validity of using *T. rex* as an indicator of a middle Miocene age.

Class Scaphopoda

Family Dentaliidae

Dentalium (*Rhabdus*)

cf. *D. (R.) schencki* Moore, 1964

Figure 43

Dentalium (*Rhabdus*) *schencki* Moore, 1964:51, pl. 31, fig. 3.

This species is very abundant at Ukolnoi Island localities, and is the second most common mollusk there, after *Turritella* (*Hataiella*) *sagai*. However, complete specimens of *D. (R.)* cf. *D. (R.) schencki* are difficult to collect, because the shells are delicate and the enclosing matrix is coarse and generally crumbly. The largest intact specimen is about 60 mm long and 7 mm wide at its aperture, and most specimens in these collections are nearly as large. The shells are smooth except for incremental growth annulations, which are very coarse near the aperture and become progressively finer toward the posterior end. The shell is circular in section and the shell wall is relatively thick.

This species is very similar to *D. (R.) schencki*, owing to its size and lack of longitudinal sculpture, but imperfect preservation prevents a more confident identification. *Dentalium* (*Rhabdus*) *schencki* was first described from the middle Miocene fauna of the Astoria Formation in Oregon (Moore, 1964), and also is present in the early Miocene fauna of the Clallam Formation in northwestern Washington (Addicott, 1976). There is no other known occurrence of *Dentalium* in the Bear Lake Formation, and this is the first report of possible *D. (R.) schencki* in Alaska. Other *Dentalium* species reported from southern Alaskan Neogene faunas are distinguished from the present taxon by having longitudinal striations.

The absence of juveniles and the nearly uniform size of adults suggests postmortem sorting. Nearly all specimens are lying in parallel alignment, which also suggests that waves or currents influenced the population structure of *D. (R.)* cf. *D. (R.) schencki* at this locality.

Modern *Dentalium* species live in a wide variety of depths and temperatures, so detailed paleoecological information cannot be inferred for the Ukolnoi Island specimens. However, *D. (R.) schencki* in the Astoria Formation is associated with inner-shelf faunas (Moore, 1964).

LOCALITY INFORMATION

Most of the specimens are housed in the U.S. Geological Survey, Branch of Paleontology and Stratigraphy, Menlo Park, California, except for a few in the Natural History Museum of Los Angeles County, Invertebrate Paleontology Section, Los Angeles, California. Illustrated specimens are deposited in the U.S. National Museum of Natural History, Washington, D.C.

All localities are in strata of early middle Miocene age in the Bear Lake Formation.

M7152. Shoreline exposure on south shore of Ukolnoi Island, about 120 meters north and 240 meters west of SE corner of section 29, T. 57 S., R. 81 W., Port Moller (A-5) quadrangle, Alaska Peninsula, southwestern Alaska; latitude 55°12.5'N, longitude 161°35.8'W. Collected by L. Marinovich, Jr. and H. McLean, 1977; field locality 77AM22; equivalent to LACMIP locality 11011.

M7153. Same general locality as M7152, above, but about 60 to 120 meters southwestward along sea cliff. Collected by L. Marinovich, Jr., 1977; field locality 77AM23; equivalent to LACMIP locality 11012.

M7154. Same general locality as M7153, above, but 60 to 120 meters southwestward along sea cliff. Collected by L. Marinovich, Jr., 1977; field locality 77AM24; equivalent to LACMIP locality 11013.

M8329. Sea cliff exposure on unnamed peninsula of the Alaska Peninsula mainland that is east of Balboa Bay, at about 183 meters north and 290 meters west of SE corner of section 4, T. 53 S., R. 73 W., Port Moller (C-2) quadrangle, Alaska Peninsula, southwestern Alaska; latitude 55°31.65'N, longitude 160°27.83'W. Collected by J.E. Case, 1983; field locality 83ACe87.

M8331. Same general locality as M7152, above. Collected by J.W. Miller, 1983; field locality 83AJm616; equivalent to LACMIP locality 11014.

M8391. Along same sea cliff exposure as M8329, above, but 183 meters to the south of M8329; along southern boundary of, and 300 meters west of SE corner of section 4, T. 53 S., R. 73 W., Port Moller (C-2) quadrangle, Alaska Peninsula, southwestern Alaska; latitude 55°31.60'N, longitude 160°27.80'W. Collected by F.W. Wilson, 1982; field locality 82AWs39.

M8894. Same locality as M7152, above; collected by R.L. Detterman and M.E. Yount, 1985; field locality 85AYb819.

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